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EXPERIENCE IN TUNING THE HIGH-FREQUENCY CHANNELS OF OVER-  
HEAD TRUNK LINES UNDER SEVERE METEOROLOGICAL CONDITIONS

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Yu. D. Farber

The causes of interruption of communications along high-frequency channels of the V-12 system under severe meteorological conditions are analyzed and simple measures are proposed which permit a reduction in outages of trunk lines caused by icing of wires.

One of the most pressing problems confronting long-distance communications technicians is the provision of uninterrupted communications along high-frequency channels of overhead trunk lines under severe meteorological conditions. Notwithstanding the fact that the length of interruption of communications due to ice formation has been considerably reduced in recent years by the installation of VUS-12 equipment and the timely removal of precipitation from conductors, a further reduction in channel outages is quite necessary. It should be pointed out that analysis of communications operations under unfavorable meteorological conditions is not performed systematically and in many cases the actual cause of the interrupted operation remains unexplained. Observations performed by the Installation and Measurement Administration of the Mezhgorsvyaz' stroy Trust in the process of tuning trunk lines show that the efficiency of channels of the V-12 system may be increased by more expedient selection of certain parameters of the equipment. The results of these observations are presented below and simple procedures for reducing operational failures of trunk lines are recommended.

Causes of Interruption of Communications Along Channels of the V-12 System

Observations have established that the appearance and gradual increase in intensity of ice formation on conductors have the following effects. The gain of the PV-12 stations gradually increases, causing an increase in noise; this is especially noticeable in channels in the A-B direction. When the gain becomes sufficiently great, nonlinear current transfers characteristic of overloading of line amplifiers occur and the needles of the current-monitoring indicators begin to fluctuate. The flat regulators of the A-B direction at one or several PV-12 stations proceed to the extreme (maximum) positions, after which the indicator readings decrease and the zero signals of the monitor current of flat regulation appear. With this the noise disturbance becomes extremely great, but in most cases communications are maintained even though with reduced quality. Further increase in losses over repeater sections causes cessation of operation along the channels in the A-B direction due to the impossibility of distinguishing the speech signals from the noise caused by interference and nonlinear current transfers.

As is known, inadequate difference between the signal level and the noise level in a channel is due to the fact that the level of the signals at the input of one or several repeaters is below the minimum permissible value. If it is assumed that the total noise power in the channel is the sum of the noise originating in the individual repeater sections, then, neglecting the noise originating in those sections in which at the given moment there is no intensive formation of ice,

$$P_{in} = \Delta p + p_n + 0.5 \ln n, \quad (1)$$

where  $p_{in}$  is the minimum permissible value of the measuring level at the inputs of the repeaters,  $\Delta p$  is the minimum difference of the signal level and the noise level of the channel at which operation is not disturbed,  $p_n$  is the level of the noise introduced by and penetrating to the end of a given repeater section within the bandwidth of a single channel of the V-12 system, and  $n$  is the number of repeater sections in which at the given moment ice formation is intensive.

Normal operation of the system, including operation of the ARU [automatic gain control] units, will be insured if attenuation in the repeater section does not exceed

$$b = P_{pre-out} - P_{in} = P_{pre-out} - \Delta p - p_n - 0.5 \ln n \quad (2)$$

(where  $P_{pre-out}$  is the measurement level at the output of the preceding repeater) and if the gain of the given repeater is sufficient to provide a normal value for measured output.

If the section losses exceed the value determined by formula (2), or even if the attenuation does not reach this value and cannot be compensated due to inadequate gain of the intermediate repeaters, channel operation ceases. Moreover, overloading of the repeaters may interrupt operation, which is discussed below.

The greater the maximum permissible section losses as determined by formula (2), the shorter the duration of the channel outages caused by the first of the above causes. Analysis of the values entering into the right-hand member of this formula shows that it is not possible to increase the maximum permissible section losses without substantial alteration of equipment and without the adoption of special measures for suppression of noise (decreasing  $\Delta p$  and  $p_n$ ). The duration of outages due to the second and third causes can and must be shortened by increasing the gain of the intermediate repeaters and eliminating the factors causing overloading of the repeaters.

It is necessary to point out that determination of the maximum permissible section losses is made difficult by the lack of exhaustive data on the quantities entering the right-hand member of formula (2). Measurements performed by Engineer M. I. Rczovskaya show that in different trunk lines these quantities have different values varying with time and varying over a rather wide range with changes in meteorological conditions.

If, as is usually done in designing, it is assumed that  $\Delta p = 3.6$  nepers (which corresponds to a noise voltage of 7.3 mv at a point with a reference level of -0.8 neper),  $p_n = -9.4$  nepers, and  $n = 5$  (the most intense icing usually occurs over a section about 400 km long), then the maximum permissible section losses of a trunk line equipped only with PV-12 repeaters is 7 nepers. The maximum-gain frequency characteristic of these repeaters for currents transmitted in the A-B direction is a straight line connecting the points corresponding to 5 nepers at a frequency of 92 kc and 9 nepers at a frequency of 143 kc. For currents transmitted in the B-A direction the maximum gain of the PV-12 repeater is 5.3 nepers.

The maximum gain of PV-12 repeaters exceeds 7 nepers only for currents of a frequency greater than 118 kc. Consequently channels employing currents of a frequency less than 118 kc will be inoperative due to insufficient gain of the PV-12 repeaters in those cases and on those sections where the above assumed initial data apply.

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The inadequate gain of PV-12 repeaters is of greatest significance for currents with a frequency of 92 kc. This also explains the cases of cessation of the flat-regulation pilot current in the A-B direction at moments when operation of the channels is still undisturbed. For example, Figure 1a gives the diagram of the measurement levels of a current with a frequency of 99 kc (the side frequency of channel 11), explaining the causes of interruption of operation on channel 11. The dotted line in this figure indicates the change in the levels in the case where for currents with a frequency of 99 kc the gain of the PV-12 repeaters is increased by 0.9 neper; in this case channel operation is undisturbed.

If VUS-12 repeaters are located on the trunk line, maximum attenuation along sections following these repeaters will be 1.5 nepers less than the previously found value. But, in order to insure normal operation of the system (including operation of the ARU units) it is necessary that the PV-12 repeaters following these sections boost the output measurement level to the initial value of 2 nepers. For this purpose the condition  $S = b + 1.5$  nepers must be fulfilled; hence, the gain requirements of the PV-12 repeaters remain unchanged.

Under unfavorable meteorological conditions the output levels of the flat-regulation pilot current in the A-B direction will be lowered due to the inadequate gain of the PV-12 repeaters for currents with a frequency of 92 kc, with the result that operation of the ARU units will be disturbed. The current levels of the side frequencies (below 118 kc) will also be lowered, with the result that the signal levels at the input ends of the succeeding VUS-12 repeaters will be intolerably low. In the case of unfavorable distribution of section losses the inadequate gain of the PV-12 repeaters will cause interruption of channel operation. For example, Figure 1b shows the diagram of the current level of the side frequency of channel 11 measured on one of the trunk lines after communications along this channel had been interrupted. The dotted line in this figure shows that as a result of an increase in the gain of the PV-12 repeaters for currents of this particular frequency disturbance of communications was avoided.

The causes of repeater overloads observed during unfavorable meteorological conditions may be explained by an analysis of the results of measurements performed by Engineer V. A. Ravvey. It was established from these measurements that in the case of severe meteorological conditions the frequency characteristic of the circuit losses for currents with a frequency of 92-143 kc departs from a straight line (curve 1 in Figure 2). Since the gain of the PV-12 repeaters is determined by the losses of the monitor currents of 92 and 143 kc in the preceding sections and the frequency characteristic of the gain of these repeaters is linear (curve 2 in Figure 2), for currents of the middle channels the gain of the repeaters exceeds the necessary value. According to A. V. Ravvey's data the indicated excess of gain amounts to 0.05-0.1 neper for each section included within the intensive icing sector and, gradually increasing, reaches 0.7 neper at the end of the trunk line, which also conduces to overloading of the repeaters and interrupts channel operation.

It is evident that in order to decrease the number and duration of outages of channels of the V-12 system under unfavorable meteorological conditions it is necessary to increase the gain of the PV-12 repeaters for currents of 92-118 kc (it is also advisable to consider increasing the gain for currents of 36-84 kc) and to eliminate the possibility of repeater overloads due to disparity between the frequency characteristics of the repeaters and the section losses. The above considerations must be kept in mind both for the operation of trunk lines and for the production of V-12 equipment.

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### Recommendations for V-12 Systems under Operating Conditions

The workers of the Installation and Measurement Administration have developed the following measures for increasing the efficiency of V-12 systems in operation.

The specified slope of the frequency characteristic of the repeater filter connected to the PV-12 units within the negative feedback loop of the line amplifier in the A-B direction and consisting of inductance  $L$  and capacitance  $C_{20}$  is changed by a resistor with a value of approximately 4.3 kilohms. (See collected articles in Tekhnika svyazi. 12-kanal'naya sistema vysokochastotnogo telefonirovaniya po vozdushnym liniyam svyazi tipa V-12) [Communications Engineering. 12-Channel System of High-Frequency Telephony on Open-Wire Communications Lines (Type V-12)], Svyaz' izdat, Moscow, 1952, page 95.) While the gain of the repeater remains unchanged for currents of 143 kc, it increases by 1.1 nepers for currents of 92 kc and amounts to 6.1 nepers for the currents of all the remaining transmitted frequencies. The gain of the PV-12 repeater increases correspondingly. In this case the frequency characteristic of the maximum gain of the repeater has the form of a straight line joining the points corresponding to 9 nepers at a frequency of 143 kc and 6.1 nepers at a frequency of 92 kc. When the slope control is set at the fifteenth division the repeater, gain for the 92-kc currents becomes greater than for the 143-kc currents. As a result there is considerably less need for additional flat regulation in the given direction of transmission.

In parallel with  $R_5$  at the PV-12 repeaters in the cathode circuit of the first tube of the line amplifier in direction A-B there is connected a filter consisting of a series-connected coil, capacitor, and resistor. The capacitance and inductance are so chosen that voltage resonance occurs in the filter at 143-146 kc. The resistance is so chosen that upon connecting the tuned circuit to resistor  $R_5$  the repeater gain for the 143-kc currents is increased by 0.1 neper, remaining practically unchanged for currents with a frequency less than 135 and more than 153 kc (the given results were obtained with  $L = 4$  millihenries,  $C = 300$  micromicrofarads, and  $R = 390$  ohms). In operation on a trunk line the frequency characteristic for the gain of a repeater equipped with the described filter has the form of curve 3 in Figure 2. As is seen from the figure, the repeater gain for currents of certain frequencies of the transmitted band is inadequate (by several hundredths of a neper), but nevertheless the possibility of overloading of the repeater is completely excluded.

On those trunk lines where severe meteorological conditions threaten to interrupt operation in the B-A direction as well, the gain of the PV-12 repeaters for the currents transmitted in this direction may be increased by decreasing the negative feedback in the line amplifier and in the flat-regulation amplifier. If in the negative-feedback circuit of the line amplifier in the B-A direction an additional 47-kilohm resistor is connected in series with  $R_{26}$ , then the gain of this amplifier as well as the maximum gain of the PV-12 repeater for 36-84-kc currents increases by 1 neper. When the sectionalized resistor  $R_4$  in the flat-regulation amplifier was connected so that the feedback currents flowed through a 100-ohm resistance, the gain of the repeater was further increased by 0.7 neper.

It must be pointed out that the increase in gain of the PV-12 repeaters gives rise to a corresponding decrease in attenuation along the loop formed by the repeaters in both directions of transmission. Since under severe meteorological conditions the channels operate with a reduction in quality ( $U_{\text{noise}} = 7.3$  mv at a point with a reference level of -0.8 neper), it may be considered that the decrease in loop attenuation



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arising from the increased gain in one of the directions of transmission will be negligible. Where loop attenuation must be increased it is necessary to connect a tuned circuit with a resonant frequency of 86 kc in parallel with the transmission circuit in the B-A direction or a similar tuned circuit with a resonant frequency of 83 kc in parallel with the transmission circuit in the A-B direction. Connection of each of these tuned circuits without changing the characteristics of the transmission circuits for currents transmitted in the given direction increases the loop attenuation at the resonant frequency of the tuned circuit by not less than 0.7 neper.

All of the described measures are necessary only under severe meteorological conditions. Hence it is advisable to fasten the additional elements by means of U-shaped straps. It is recommended that the resistors increasing repeater gain for 92-kc currents and the tuned circuits increasing repeater gain for 143-kc currents be connected and disconnected simultaneously with connection and disconnection of the amplifier equipment of the VUS-12 repeaters in the A-B direction. The resistors increasing repeater gain in the B-A direction and the tuned circuits increasing loop attenuation need be connected only in those cases where, upon connecting the amplifier equipment for the B-A direction at the VUS-12 repeaters, the gain of the PV-12 repeaters for 80-kc currents is inadequate. It is necessary to connect the above elements at the first signs of decreased intensity of ice formation on the conductors.

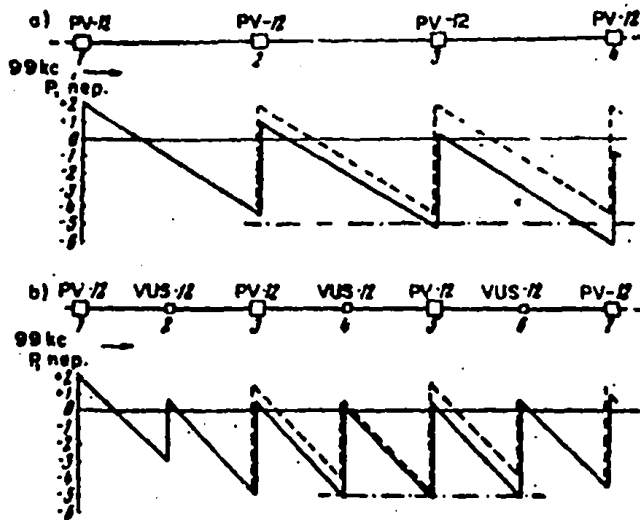


FIGURE 1

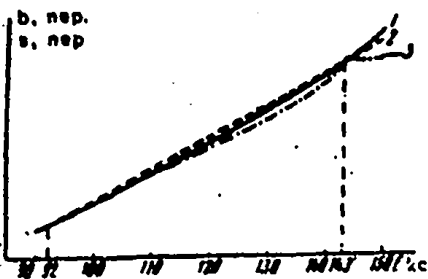


FIGURE 2

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